



Environmental Programs and Strategies in the North American Electronics Sector: Addressing Global Expectations

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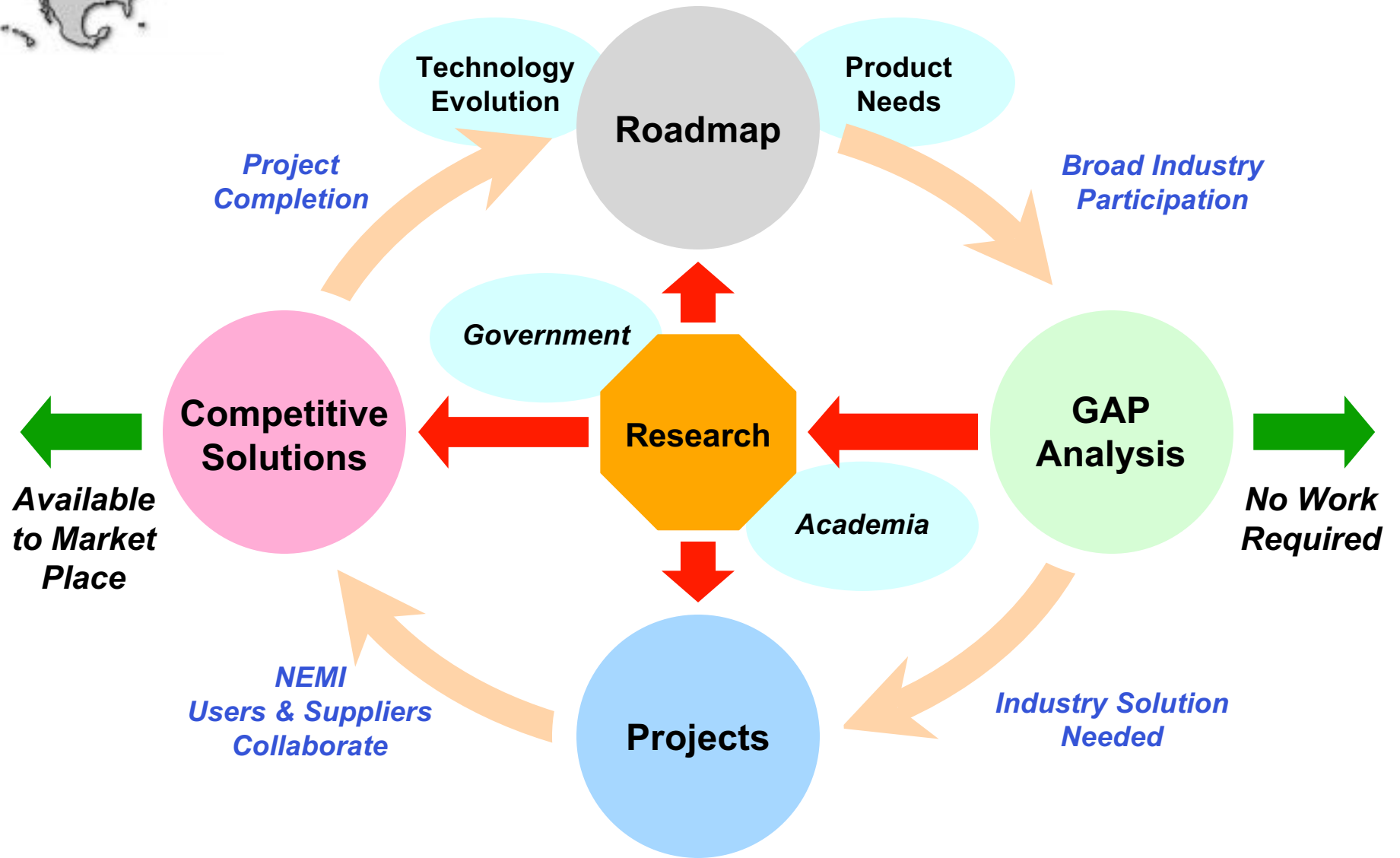


Outline

- **National Electronics Manufacturing Initiative (NEMI) 2002 Environmentally Conscious Electronics Roadmap**
- **Addressing the RoHS Directive**
 - ✓ **US Pb-Free Activities (NEMI)**
 - ✓ **Materials of Concern (EIA)**
- **Addressing the WEEE Directive (AeA and NEMI)**
- **Needs and Direction of R&D**
- **Conclusions**



NEMI Roadmap Cycle

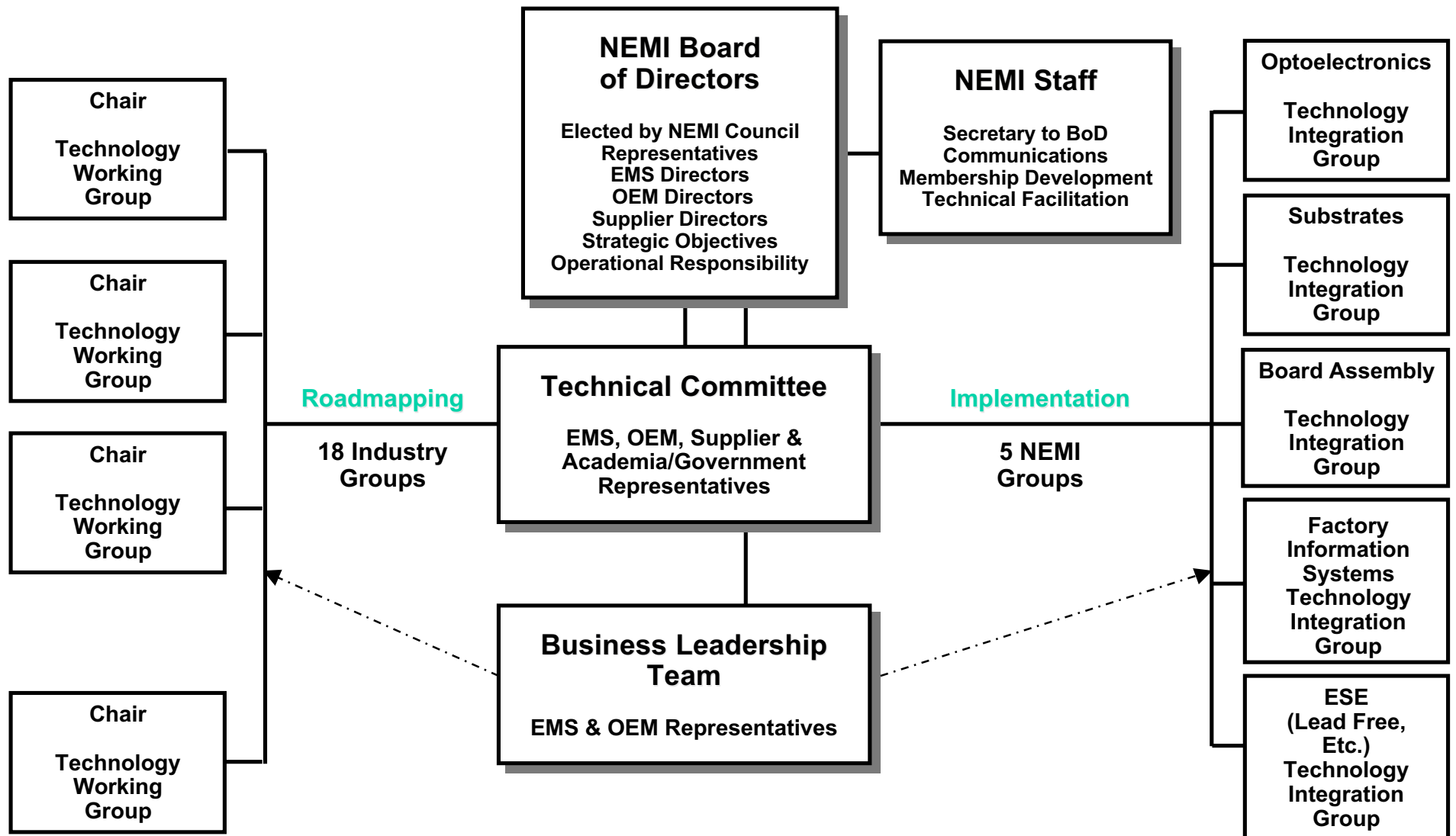


NEMI Implementation Cycle

Connect with and Strengthen Your Supply Chain



NEMI Organization



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NEMI 2002 Environmentally Conscious Electronics Roadmap

Situation Analysis: Legislative

- **Increasing Environmental Legislative Activity**
 - ✓ **End-of-Life Disposal Legislation in Europe, United States, and Japan**
 - **Electric Home Appliances Recycling Law in Japan (1998)**
 - **WEEE in Europe (2002)**
 - **Automotive Legislation in Europe**
 - **EOL legislation pending in 20 states**
 - ✓ **Hazardous Materials in Europe, Japan, and U.S. States**
 - **RoHS in Europe (Pb, Br-FR, Cd, Hg, Cr+6) (2002)**
 - **Proposition 65 in California**
 - **Hg in New England**
 - **Materials Declaration by Suppliers**

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WEEE Goal: Take-back and Recycling

- **Take-back**
 - ✓ Producers will fund collection, treatment, recovery & disposal of End of life electronics from the final holder.
- **Treatment**
 - ✓ Batteries, PWBs (mobile phones generally, else > 10 cm²), external electric cables, and plastic containing brominated flame retardants must be removed from the product and treated separately.
 - ✓ Rate of recovery must reach 70% - 80% of WEEE sent for treatment.
- **Documentation**
 - ✓ Must provide recyclers information on disassembly, components, materials, and location of dangerous substances.
 - ✓ The crossed dust bin symbol has to be put on product or packaging.



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RoHS Goal: Eliminate Hazardous Substances

- **Member States shall ensure that, from July 1, 2006, new electrical and electronic equipment put on the market does not contain the following substances.**
 - ✓ **Lead (Pb)**
 - ✓ **Mercury (Hg)**
 - ✓ **Cadmium (Cd)**
 - ✓ **Hexavalent chromium (Cr VI)**
 - ✓ **Polybrominated biphenyls (PBB)**
 - ✓ **Polybrominated diphenyl ether (PBDE)**

Parliament may ban other hazardous substances in the future

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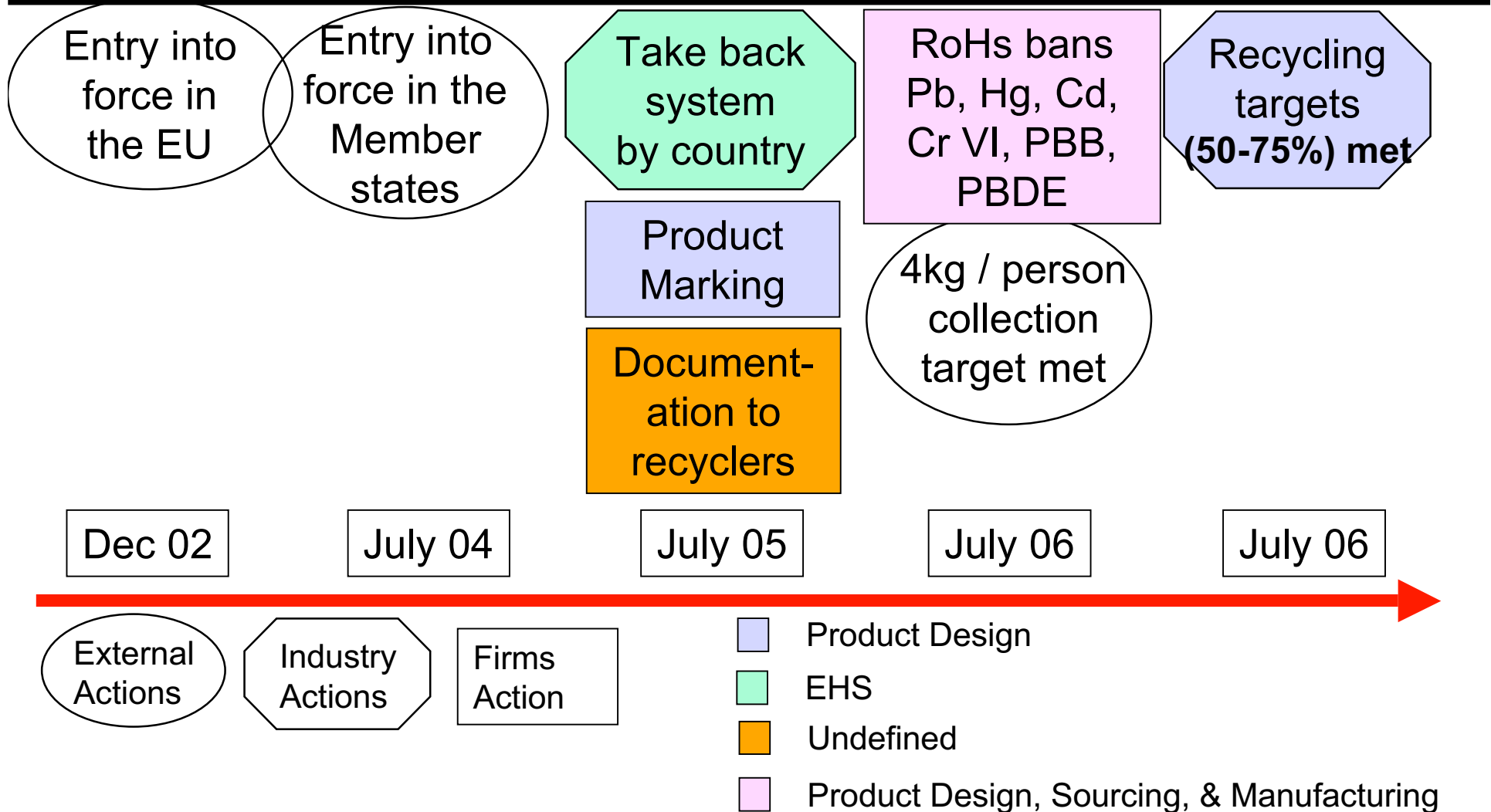
RoHS Exclusions: Lead

- Lead in high melting temperature type solders (i.e. tin-lead solder alloys >85% lead)
- Lead in solders for servers, storage and storage array systems (exemption granted until 2010)
- Lead in solders for network infrastructure equipment for switching, signaling, transmission as well as network management for telecommunication
- Lead in electronic ceramic parts (e.g. piezoelectronic devices)
- Commission evaluates the exemptions with a view to setting a specific time limit for this exemption

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RoHS and WEEE Timeline



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Situation Analysis: Alternative Technology

- **Alternative Technology Base**
 - ✓ Pb-free solders and process-NEMI Project Activity
 - ✓ Br-Free PWBs and plastics are commercially available
 - ✓ Cd, Pb and Hg free plastics are available
 - ✓ Cr+6 alternatives are emerging
- **Successful Implementation into Products**
 - ✓ Widespread introduction of Pb-free solders and Br-free PWBs in Japan
 - ✓ Limited introduction of Pb-free solders and Br-free PWBs in North America
 - ✓ High temperature component qualification is an issue
 - ✓ Pb-free components are becoming available; however, lead finishes are still in debate for high reliability applications.

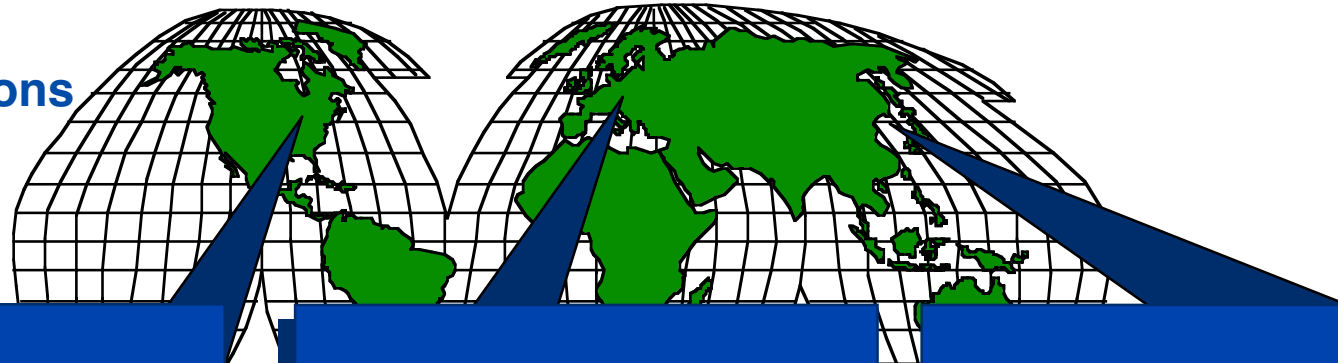
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Regional Focus of R&D

Regional Drivers

Global Solutions



United States

- Regulation Driven
- Application Focus
- R&D Linkages between industry, Gov., Academia
 - Viable analytical tools for Industry
 - Alternative Materials
 - Alternative Systems

Europe

- Academic & Regulation Driven
- Academic Focus
- R&D: Model Focused
 - Life Cycle Analysis
 - Material Flow Analysis
 - Product Service Systems

Japan

- Government/Industry Driven
- Market Focus
- R&D: Product Focused
 - Hybrid Engines
 - Halogen Free Plastics
 - Pb-Free Products

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Situation Analysis: Market

- **Customers**

- ✓ **Industrial**

- **Materials Declarations are required in the Auto Industry and will Penetrate the Electronics Industry**

- **Standard information declarations developed by EIA**
 - **No Automotive Standards**

- ✓ **Consumers**

- **Limited Markets**

- **Environmental Labels**

- ✓ **Increasing pressure for labels**

- ✓ **Energy use is widely labeled**



NEMI 2002 Roadmap: Gap Analysis

- **The most pressing implementation issue for Pb-free solder is the availability of components specified to meet higher soldering temperatures**
- **No standards exist for communication of “Materials of Concern” Information.**
- **North American OEMs are generally not prepared to implement the Product Take Back requirements of WEEE**
- **There are no robust LCA/LCI tools**
- **The OEMs need to focus on eliminating hazardous materials in Cables and Accessories**



Recommendations

To remain competitive global electronics firms will need to:

- Develop, qualify, and introduce new materials, components, and processes in 2002-6 to enhance recyclability, improve energy efficiency, and reduce ecological impact.
- Develop and implement efficient methods for data exchange of environmental attributes to meet the requirements of European and Japanese regulations on Electronics and Automotive products.
- **Educate the supply chain to the new materials requirements and end-of-life responsibilities.**
- Develop tools to address the complex decision and tradeoff process to develop products with minimal environmental burden.

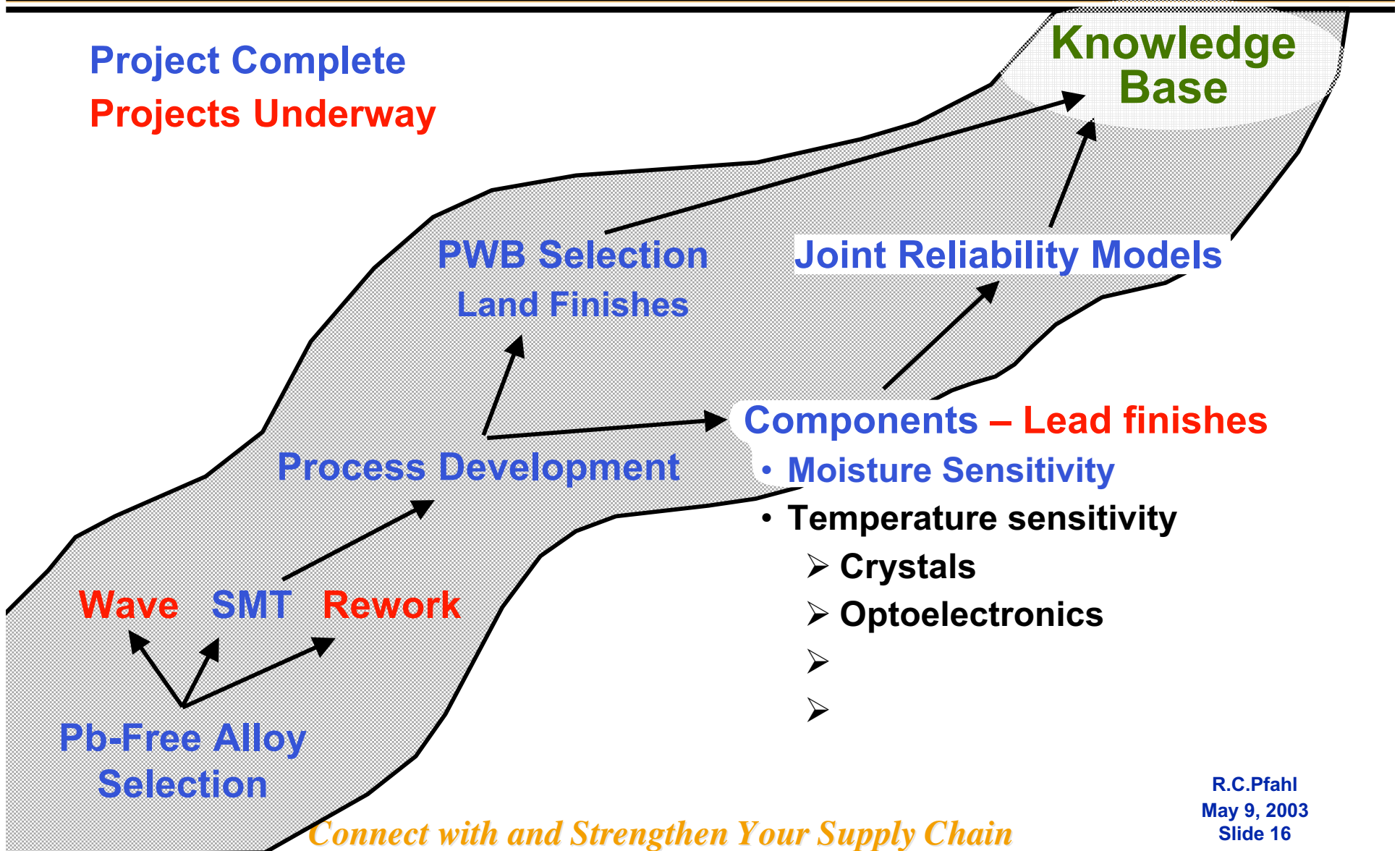


Addressing the RoHS Directive

- **North American Pb-Free Activities (NEMI)**
 - Solder Alloy
 - Components/PWB
 - Process Development
 - Solder Reliability
 - Tin Whiskers
- **Materials of Concern (EIA)**
 - ✓ Materials Declaration Guide
 - ✓ Regulatory Tracking Tool



North American Pb-Free Activities (NEMI) Lead-Free Roadmap





Roadmap of Lead-Free Assembly

- **Driving forces for Lead-Free Assembly are many**
 - ✓ Market
 - ✓ Regulation
 - ✓ Reputation
- **Impact of these forces varies depending on**
 - ✓ Product segment (e.g. consumer, business, automotive)
 - ✓ Regional focus
 - ✓ Company strategy
- **NEMI Strategy is to ensure supply chain readiness for Lead Free Assembly**
- **Actual crossover is a business decision (based on above factors)**



Participants in NEMI Pb-Free Projects

OEMs/EMS

Alcatel
Celestica
Cisco

Delphi/Delco
Hewlett-Packard
IBM
Intel
Jabil
Kodak
Lace Technologies
Lucent
Motorola
Nortel Networks
Sanmina-SCI
Solectron
StorageTek

Material Suppliers

Alpha Metals
Cookson
Heraeus
Indium
Kester
Shipley

Components
AMD
ChipPac
Intel
Motorola
Texas Instruments

FCI Electronics

Govt. & Other

NIST
SUNY-B/IEEC
IPC

Equipment

Agilent
CMAP
BTU
Universal
Vitronics-Soltec

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Environmentally Conscious Electronics (ECE) TIG Projects

ECE Technology Integration Group (TIG)

Chair: Rick Charbonneau, StorageTek

Lead-Free Assembly

Chair:
Edwin Bradley, PhD Motorola
Co-Chair:
Rick Charbonneau, StorageTek

Lead-Free Assembly & Rework

Chair:
Gerald Gleason, HP
Co-Chair:
Charlie Reynolds, IBM

Tin Whiskers HAST

Chair:
Nick Vo, Motorola
Co-Chairs:
Jack McCullen, Intel
Mark Kwoka, Intersil

Tin Whiskers Users Group

Chairs:
George Gaylon, IBM
Richard Coyle, Lucent

Tin Whisker Modeling

Chair:
George Gaylon, IBM
Co-Chair:
Maureen Williams, NIST

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Pb-Free Project Summaries

- **Lead Free Assembly Project:** (Edwin Bradley, Motorola, Chair; Richard Charbonneau, StorageTek, Co-Chair)
Project Groups:
Pb Free Alloy Group, Chair: Carol Handwerker, NIST
Pb Free Process Group, Chair: Jasbir Bath, Solectron
Pb Free Component Group, Chair: Richard Parker, Delphi-Delco
Pb Free reliability Group, Chair: John Sohn, Lucent (retired)
Status: Project Started, 1Quarter 1999 - **Completed, Q4, 2002**
- **Advanced Pb-free Assembly and Rework Development Project:** (Chair Jerry Gleason, HP; Co-Chair Charles Reynolds, IBM) Status: Project Start, February 2002 **Project 15% Completed**
- **Tin Whisker Modeling project:** (Co-chairs George Galyon, IBM, Maureen Williams, NIST) Status: Project Start, February 2002 **Project 50% Completed**
- **Tin Whisker Accelerated Test Project:** (Nick Vo, Motorola, ChipPAC, Inc., Chair, Mark Kwoka, Intersil and Jack McCullen, Intel Co-Chairs) Status: Project Start, February 2002 **Project 90% Completed**
- **Tin Whisker Users Group:** (Co-chairs George Galyon, IBM, Richard Coyle, Lucent) Status: Project Start, February 2002 **Project 90% Completed**
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Solder Alloy Project

Mission: Provide critical data and analyses needed for making decisions with respect to solder alloys, manufacturing, and assembly reliability.

- ✓ **NEMI chose Sn-3.9Ag-0.6Cu, rest of world moving close to that choice**
 - **Worked with NIST to characterize alloy phase diagram.**
- ✓ **Developed “best practices” experimental procedures to measure the mechanical, thermal, electrical and wetting properties of lead-free solders**
- ✓ **Developed Solder Reliability Modeling Guidelines**
 - **Critical review of reported deformation data and models**



Alloy Team Accomplishments

- ✓ Lead-free solder reference database available.
- ✓ Determined ternary eutectic melting temperature of Sn-3.9Ag-0.6Cu.
- ✓ Investigated patent and materials property issues for Task Force selection of Sn-3.9Ag-0.6Cu for reflow and Sn-0.7Cu for wave.
- ✓ Examined sensitivity of melting behavior of Sn-Ag-Cu to composition and temperature in response to request from team members.
- ✓ Held workshop on modeling and data needs for lead-free solders with workshop report being used as roadmap for developing and analyzing data.
- ✓ Public domain properties and reference databases available on NIST website.
- ✓ Database developed for archiving information on NEMI thermal cycling test vehicles needed for FEA.



Component Project

Mission: Identify and recommend the best materials for the supplier industry to use, which meet the Pb-free requirements set by the main task group.

- ✓ **Characterized component survivability at elevated reflow temps.**
 - Some degradation, but materials available to meet needs.
- ✓ **Characterized the optimum operating profile of maximum time, temperature and environment exposures.**
- ✓ **Recommendation for component temperatures**
 - JEDEC used our data for revised J-STD-020B standard, consistent with our position: 250°C -5/+0



Component Project Conclusions

- Large ICs stayed below **240°C peak** temperatures
 - ✓ Smaller ICs and discrete parts stayed below 250°C peak temperature
 - ✓ Manufacturing tolerances were not added to the 240°C goal:
 - Oven repeatability
 - Thermocouple repeatability (mounting, tolerance, equipment)
 - Machine to machine reproducibility
- With appropriate management of reflow process, 240C max achievable for large IC's, 250C max for small IC's on Boards ≤0.92" thick



Process Development Project

Mission: Demonstrate manufacturing processes for lead-free soldering of printed wiring board assemblies

- ✓ Most thorough study of lead-free assembly to date
- ✓ Processes developed on existing tools and equipment
- ✓ Transferred to 3rd party for Reliability hardware build
- ✓ No major problems encountered during builds
- ✓ Agilent demonstrated Feasibility X-Ray inspection for Pb-Free
- ✓ Employed Acoustic microscopy before/after reflow
 - No damage due to reflow
- ✓ Evaluated automated optical inspection tooling
- ✓ Solder paste performance – Excellent printability and wetting

Demonstrated high quality Pb-free solder joints for reliability testing

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Process Development Project Conclusions and Recommendations

- **Lead-free solder assemblies successfully manufactured with existing assembly process equipment**
- **Materials used for lead-free soldering: Adequate**
 - ✓ Solderability of lead-free solder paste is reduced compared with tin-lead.
 - ✓ Voiding tends to increase with lead-free solder paste especially with tin-lead components.
- **Equipment Used: Most existing production equipment is adequate for SMT lead-free assembly**
- **Inspection Equipment: X-Ray and Acoustic Inspection tools adequate. More work needed on AOI**



Reliability Project

Mission: Perform reliability testing for selected solders, components, and board finishes using an approved test vehicle.

- ✓ Thorough experiment covering various components, solder/lead combinations, failure analysis, statistical analysis.
- ✓ Reliability tests
 - Thermal Cycling (-40 to 125°C, 0-100°C)
 - Three-point Bend Testing of BGAs
 - Electrochemical Migration
- ✓ Very Detailed Failure analysis and root cause of TC failures
 - Red dye penetrant
 - Metallurgical cross-section and analysis

Demonstrated Pb-free Joints are more reliable than Tin-lead

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NEMI Pb-free Reliability Project Conclusions

- **Thermal Cycling (-40 to + 125°C and 0 to 100°C)**
 - ✓ LF (balls/comp finish - paste alloy) combinations performed equivalent to or better than Pb benchmark
 - ✓ Not as clear with mixed cell combinations
 - Most performed equivalent to the Pb benchmark
 - Two combinations performed worse
 - One combination performed better
- **3 Point Bend testing: no differences observed between the different combinations**
- **No Electrochemical Migration issues seen with LF alloy when evaluated per IPC-TM-650 Method 2.6.14.1**
- **Established technical feasibility of Pb-free processing and reliability of Pb-free solder joints.**

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Follow-on Work

- **Much work still needed to implement/understand SnAgCu solders. Projects underway on**
 - ✓ **Board Laminates & ability to withstand higher temp.**
 - ✓ **Board finishes for SnAgCu soldering**
 - ✓ **Component lead finishes**
 - **Tin whisker accelerated stress testing***
 - **Fundamental understanding of tin whisker formation**
 - ✓ **Component replacement & rework**
 - **Thin (0.060") and thick (0.130") Boards**
 - ✓ **Wave Solder for Pin-in-hole components**
 - ✓ **Reliability modeling of SnAgCu solder joints**
- * **Sharing results with JEITA & ITRI UK.**

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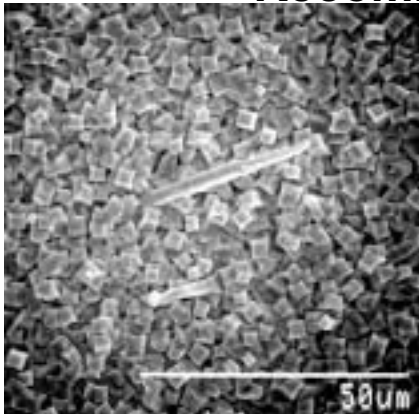
Advanced Pb-free Assembly & Rework Project

- **Chair: Jerry Gleason – HP**
- **Co-Chair: Charles Reynolds, IBM**
- **Pick up Areas not covered by initial NEMI work:**
 - ✓ **Large, Thick Boards**
 - ✓ **Wider range of components**
 - ✓ **Rework (including design rule impact)**
 - ✓ **Combined surface and thru-hole assembly**



Tin Whisker Projects

- **Modeling Chair: George Gaylon, IBM**
- **HAST Chair: Nick Vo, Motorola**
- **Objectives**
 - ✓ **Determine underlying mechanisms of whisker formation**
 - ✓ **Develop an accelerated test to determine the potential for whisker formation**
 - ✓ **Determine the acceleration factors to predict long term tendency to whisker**
 - ✓ **Recommend industry standard test to IPC/JEDEC**



Example of tin whisker

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Pb-Free Technology Status

- **The NEMI project has moved the industry forward in knowledge and understanding of Pb-free materials and processes.**
- **Continuing to work to fill in knowledge Gaps.**
- **Building the knowledge base equivalent to today's SnPb solder will not be done overnight.**
- **NEMI is open to working with other groups to insure that all major gaps are addressed in an effective & timely manner.**



Materials of Concern (EIA)

EIA Information and Supply Chain Management Tools

***EIA: Helping the Electronics Industry Achieve
Strategic Environmental Advantage***

R.C.Pfahl
May 9, 2003
Slide 33



EIA's Material Declaration Guide

- **Companies use material declaration questionnaires to track material composition of components they purchase to ensure global sale**
- **Proliferation of questionnaires makes task inefficient and costly**
- **In 2000, EIA members asked EIA to take lead in development of industry guidance**

EIA: Helping the Electronics Industry Achieve Strategic Environmental Advantage

Material Declaration Status



- EIA Guide finalized February 2001
- Japanese and Europeans have similar efforts
- US-EU-Japanese Chemical lists, thresholds and formats differ
- Joint meetings have been held to harmonize
- Global standard expected in 2003.

Organizations Participating in Standardizing Material Declarations

- The European Information, Communications and Consumer Electronics Industry Technology Association (EICTA),
- The Japanese Green Procurement Supply Survey Initiative (JGPSSI) – a workgroup of the Japanese Electronics & Information Technology Industries Association (JEITA)
- The Electronic Industries Alliance (EIA)

EIA: Helping the Electronics Industry Achieve Strategic Environmental Advantage



Regulatory Tracking Tool

- **Regulatory Tracking Tool - internet based service that provides members with comprehensive legislation and regulatory information on international and domestic product requirements**

EIA: Helping the Electronics Industry Achieve Strategic Environmental Advantage



EIA Regulatory Tracking Tool

- **Why was it developed?**
- **Increased and often conflicting regulation at international, federal, and state levels may:**
 - ✓ Increase supply chain information requests.
 - ✓ Restrict free trade of electronics worldwide.
 - ✓ Result in inconsistent product requirements.
 - ✓ Increase manufacturing and marketing costs.
 - ✓ Reduce industry competitiveness.
 - ✓ Impact product reliability and effectiveness.
 - ✓ Increase environmental harm.
- **Companies need a tool to manage this information.**

EIA: Helping the Electronics Industry Achieve Strategic Environmental Advantage



Addressing the WEEE Directive (AeA and NEMI) North American Status

- **North American OEMs are generally not prepared to implement the Product Take Back requirements of WEEE**
- **NEMI has taken the leadership by hosting a product take-back workshop in October 2002 to educate supply chain on new end-of-life requirements members**
 - ✓ **AEA Provided Support on Legislative Status**
 - ✓ **EIA Provided Support on Materials Declaration**



Identified Gaps: 2002 NEMI Roadmap Environmentally Conscious Electronics

- **North American OEMs are not prepared to implement the Product Take Back requirements of WEEE**
- **The most pressing issues for the implementation of Pb-free solder are:**
 - ✓ **The availability of components specified to meet higher soldering temperatures**
 - ✓ **Issues of alternative finishes**
 - ✓ **Pb-Free Assembly & Rework of large systems**
- **The OEMs need to focus on eliminating hazardous materials in Cables and Accessories**
- **No standards exist for communication of “Materials Content Declaration” Information.**



Potential Activities

Identified at March 7, 2003 Gap Analysis Meeting

- **Standards for communication of “Materials Content Declaration” Information.**
- **Supply Chain Readiness**
 - ✓ Educating Distributors
 - ✓ Flushing out the supply chain
 - ✓ Labeling Pb-free semiconductor components
- **Ecodesign-Guidelines, Tools, Templates, Metrics**
- **Take Back, Recycling Infrastructure (Europe)**
 - ✓ Benchmarking evolving services in Europe

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Organizational Challenges

- **Wide diversity in readiness of companies**
 - ✓ Leadership (differentiation)
 - ✓ Defensive (meet minimum needs)
 - ✓ “Deer in-the-headlights”
- **Response requires new functions and cross-functional teams.**
- **Wide diversity of business models within regions**
 - ✓ Vertically integrated
 - ✓ Significant outsourcing of design & manufacturing
 - ✓ Small vs. large companies
 - ✓ Different approaches for EoL management
- **Needs of companies will vary based on these variables.**
- **These variables will impact how industry groups organize collaborative efforts to meet needs.**



Next Steps

- **Meeting to further discuss closing gaps will be held on Monday, May 19, 2000 at the IEEE-ISEE**
- **Location: Cambridge Room of the Park Plaza Hotel in Boston**
- **Time: 5:30-7:00 PM**

WWW.NEMI.ORG